(E79-10262) THE ECONOMIC COSTS AND BENEFITS
OF AN INTERNATIONAL GRAIN RESERVE PROGRAM
WITH AND WITHOUT IMPROVED (LANDSAT) CROP
INFORMATION: A CASE STUDY BASED ON THE ECON
INTEGRATED MODEL, (ECON, Inc., Princeton, N. G3/43
N79-31722
HC A02/MF A01
Unclas
00262

THE ECONOMIC COSTS AND BENEFITS OF AN INTERNATIONAL GRAIN RESERVE PROGRAM WITH AND WITHOUT IMPROVED (LANDSAT) CROP INFORMATION:

A Case Study Based On The ECON Integrated Model

Summary and Overview

E7.9 - 10.262
CR-158877

ECON INCORPORATED

77-294-2
NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

FINAL

THE ECONOMIC COSTS AND BENEFITS OF AN INTERNATIONAL GRAIN RESERVE PROGRAM WITH AND WITHOUT IMPROVED (LANDSAT) CROP INFORMATION:

A Case Study Based On

The ECON Integrated Model

Summary and Overview

Prepared for

The National Aeronautics and Space Administration
Office of Applications
Washington, DC

Prepared by

ECON, Inc.
900 State Road
Princeton, NJ 08540

Under Contract No. NASW-3047

December 31, 1978

NOTE OF TRANSMITTAL

This final report is submitted to the National Space and Aeronautics Administration, Office of Applications, in fulfillment of Task No. 9, Contract NASW-3047. It is in two parts: (1) Final Technical Report, and (2) Summary and Overview. In addition, two separately bound Appendices (77-294-1A and 77-294-1B) documenting the computer work on the contract have been sent by ECON to the Technical Officer monitoring this task, Mr. S. Ahmed Meer at Goddard Space Flight Center.

ECON acknowledges the efforts of Philip Abram and David Lawson in using the ECON Integrated Model to analyze the costs and benefits of an International Grain Reserve with and without LANDSAT.

Francis M. Sand
Francis M. Sand
Task Manager

B P Miller
Bernie P. Miller
Project Director

TABLE OF CONTENTS

LIST OF TABLES

I. MAJOR THEORETICAL ISSUES

1.1 Purposes of U.S. Grain Reserve--Food Fund

The recent discussions of a U.S. grain reserve program in the U.S. Federal Government and agricultural research communities have taken place at a time when many voices in international circles have been advocating creation of an International Food Fund for the purpose of preventing famine in food-deficient countries in case of disastrous crop failures in those countries. Thus, we have two fundamentally different sets of purposes for grain storage programs:

- Foodgrain price and farm income stabilization in the United States (which includes foodgrain consumption stabilization)
- Food security for the food-deficient nations.

There is general agreement that government price and income stabilization programs are potentially beneficial to producers if managed properly, and the stabilization can also be beneficial to the entire economy, on balance. Consumers may in fact suffer losses from stabilization programs in countries in which the basic health or physical welfare of consumers is not threatened as a result of food shortages. When we consider the extreme cases of famine or widespread malnutrition, however, it is clear that the need for a grain reserve which can be utilized to prevent these dire consequences far overrides the traditional economic concerns with the consumers' pocketbooks. It is the latter use of grain reserves which we term "food security." This subject has been well-analyzed in recent studies by Johnson and Sumner [21], Reutlinger [25] and Konandreas, et al. [24]. The present case study is concerned not with food security, but with food price stabilization. To a very limited extent the use of a food fund to prevent extremely high prices could be interpreted as a form of nutritional disaster prevention, but

since we have limited ourselves to very aggregate regional entities (United States and Rest-of-World (ROW)) and more particularly because of our use of linear demand schedules, we shall avoid such interpretations.

In this case study the grain is acquired by an international authority in times of grain surplus by open market purchases at prevailing prices. The authority releases grain from the reserve to either domestic or foreign markets whenever average prices exceed a preset ceiling level for the current two-month period. Both U.S. and foreign grain market prices and grain consumption are stabilized by the intervention of the international food fund, and this is the only purpose of the food fund in our study. We are concerned with three aspects of the economics of this type of grain reserve:

1. The costs of the operation of an international grain reserve program
2. The benefits of the program
3. The effects of improved crop information on the costs and benefits of the program.

The subject is treated as generally as possible within the context of the existing ECON Integrated Model, which was created and implemented for NASA in 1974-76 in order to estimate the benefits of a worldwide LANDSAT crop survey application [13, 14, 15]. It is the Integrated Model which provides quantitative insight into the third economic aspect mentioned above, and which permits evaluation of the trade-offs between inventory and information.

1.2 Costs and Financing of a Grain Reserve

The major cost associated with the creation of the grain reserve is associated with the initial acquisition of sizable starting stocks by the food fund authority. This is necessary if the food fund is to meet its objectives with any reasonable degree of probability. Further costs are surely incurred as time goes on for subsequent foodgrain purchases, but these costs are offset to some extent by sales

of foodgrain from the fund's stocks. Inasmuch as the purchases are made at times of abundance of grain when prices are low and the sales are made at times of grain shortage when prices are relatively high (but not extreme, obviously), there is a possibility of profitable fund operations. It will be seen that, under the operational rules adopted for the study, this possibility does not materialize within the 50-year lifetime of the fund and, indeed, it would be inappropriate for the fund to be profitable in the presence of an existing competitive private grain storage industry.

We have chosen not to attempt to develop specific details of financing for the fund. The policy simulation method (see Section 2) used here does not achieve a sufficient degree of realism for financing to be relevant in this context. Thus, we assume that the countries participating in the food fund provide pro rata shares of the required initial capitalization for acquiring starting stocks of foodgrains; alternatively, one can assume that the fund obtains a single large long-term loan at zero interest charge from an international financial body such as the World Bank. It would be relatively simple to modify our results, which are intended to be only illustrative, to account for greater realism in the financing of the fund.

1.3 Benefits of a Grain Reserve

The economic welfare effects of storage of foodgrains by a governmental authority are complicated and the subject is controversial. It has been repeatedly found that estimates of the economic benefits of grain reserve programs change size or even sign as a result of varying assumptions of the economic analysis. Helmberger and Weaver [9] showed that accounting for private storage behavior in the presence of a government grain reserve program made a substantial difference to producer and consumer gains and losses. Just, et al. [23] demonstrated the importance of the nonlinearity of demand curves for determining even the signs of the consumer and producer welfare effects in a two-region world

with trade. A third theoretical issue of importance to economic analysis of this subject concerns the temporal dynamics of grain production, consumption and storage. Many published studies of the benefits and costs of a grain reserve program are based on static models. The dynamic model involves considerable mathematical complexity and requires far greater amounts of computation (see, for example, Gustafson [20] or Andrews [15]). Nevertheless, the foodgrain economy is dynamic in reality and it seems to us that a dynamic model is a minimal requirement for credibility. Related to this issue is the question of feedback from the markets to the fund authority and vice versa. There is a subtle question involved here on how the markets evaluate fund transactions, and what effect the informational flows have on both markets and fund. In the present study, we have attempted to deal with this problem through the use of a stochastic optimal control model in which uncertainties about the size of future grain harvests are specified as a probability distribution on the supply state variable. Although a full-scale infinite-horizon optimization of the model with government intervention (food fund operations) is presently beyond our capabilities, we have optimized the model for each time period with fixed rules for food fund operations, and this does include a local feedback loop between fund and market.

A limitation of the present study is that we can only consider linear demand schedules: this is a price we pay for having the dynamic and stochastic elements well represented in the model. The consumer benefits of the food fund are computed separately for each world region (United States and ROW) but the economic benefits are computed only for the entire world. The standard form of economic surplus as integral under the demand curve is used to compute benefits per period; these are then discounted at 15 percent and accumulated over the lifetime of the fund.

1.4 Crop Information and Fund Management

The instability of foodgrain prices is related in part to the natural variability of crop harvests and in part to the state of information on future crop supplies available to the market. Buffer stocks can dampen market price fluctuations and indeed we are contemplating the use of the grain reserve for this very purpose in this study. Unless these stocks are very large (which necessitates high carrying charges--storage cost and interest) the uncertainty component inherent in less-than-perfect information about the expected crop yields has a significant effect on price variability and consequently also on consumption variability. There have been suggestions that crop information improvement can be traded off against increased inventory of grains (e.g., L. Thurow [27]). It is logical that this should be true in a very simple sense: the release of reserve stocks to the market <u>can</u> hold down price increases as effectively as the release of official information on the expectation of good crop yields. But the former can surely be accomplished whenever the reserve management finds it advantageous, whereas the latter is equally surely tied to natural agricultural phenomena. The question of interest to us is: What is the economic efficiency of a grain reserve program of a specified size in the presence of an information system of specified accuracy? Our focus is accordingly on the trade-off between the benefits of increased crop forecast accuracy and the benefits of the grain reserve program in a sense which is to be detailed in Section 2. There are, of course, also costs associated with the improvement of the crop information system. The interested reader can find LANDSAT system costs in "A Cost-Benefit Evaluation of the LANDSAT Follow-On Program" [26]. The present study is, we believe, the first to estimate the quantitative effects of improved crop forecast accuracy on the costs and benefits

of a grain reserve program in an international setting, even though these estimates are admittedly rather crude due to the simplifying assumptions of the analysis.

2. STUDY METHODOLOGY

2.1 Relationship to ECON Integrated Model

The Integrated Model is a stochastic optimal control model of a two-region wheat economy, one region being an exporter, the other being an importer. The time basis of the model is a six-period year and an infinite horizon. Planting and harvesting can occur in any of the six periods; in the present implementation we have distinguished spring and winter wheat plantings and Northern and Southern Hemisphere crop calendars. There are four state variables representing wheat stocks and growing crops in each of the two regions. All of these quantities are treated as uncertain through explicit addition of a stochastic vector in the state transformation. There are five time-dependent decision variables, representing wheat planting and consumption in each region for each time period and trade between the two regions. By balance of materials, the storage decisions for each time period are implicitly also represented in the model. The model solution is obtained by maximizing expected present value of world economic surplus. This corresponds to the free market, full competition case. In order to bring food fund operations into the Integrated Model it is sufficient to add a new state variable representing fund stocks and several new decision variables representing fund sales and purchases in both regions. The policy of the fund is expressed by enlarging the constraint set to include the stabilization price bands in both regions.

Use of a rigidly fixed price band for the fund policy presents modeling difficulties in terms of the nonlinearity of some of the new constraints required to implement such a policy. An alternative method which specifies a penalty cost associated with violations of the price limits was studied and found to be

theoretically satisfactory. In practice, implementation of this approach would involve considerably more time and effort than was available for this study, due to the increased computational burden in the case of performing the optimization in a higher dimensional state space. Accordingly, we approached the task of estimating costs and benefits of a food fund as a policy simulation.

2.2 Policy Simulation Method

The policy simulation was created from the previously optimized Integrated Model by adding specific fund policy rules to the existing computer simulation of optimal wheat consumption, production, storage and trade. The Integrated Model was first solved for the given information system thus obtaining optimized economic surplus (objective function) coefficients and optimized mean values and variances for the state variables. Then, using these optimized values, the model was run in simulation mode with the fund transactions included. In this mode, the decisions are locally optimized with respect to prevailing market prices and supply uncertainties; that is, the decisions are optimal within each time period. Random numbers are used to update the state vector of wheat stocks and supplies according to the means and variances previously calculated. Then planting, consumption, storage and trade are provisionally optimized for the subsequent period. If resulting optimal prices violate fund policy, the fund intervenes, buying or selling enough wheat to bring market prices within the price band chosen for the particular simulation. After revising the decision variables to account for fund intervention, the simulation moves on to the next period. In case the fund has insufficient stocks to hold prices below the ceiling level, the simulation allows a violation of policy. Similarly, when the supply conditions and fund policy are incompatible in times of surplus (low prices), the simulation allows the price floor to be violated. Otherwise, the simulation covers a 50-year span consisting of 300

individual periods, starting with a particular fund size and maintaining a particular price band in each of the two regional markets. Costs and benefits of the fund in each region are calculated, discounted at 15 percent per annum and accumulated for final display at the end of the 50-year period, at which time all remaining fund stocks are sold.

2.3 Assumptions Used in Policy Simulation

Besides the assumptions used in the ECON Integrated Model, which are fully documented in Reference 15, the policy simulation required that the rules for operating the fund be specified in a clear, unambiguous form. To set the stage for the analysis and conclusions, we summarize these rules here. Full documentation is to be found in the first volume of this report, ECON Report No. 77-294-1.

An initial acquisition of wheat stocks by the international food fund is made by purchasing the wheat from the private sector of the United States at the model's starting price of $138 per metric ton. For 50 years, or 300 time periods, the fund is operated by

- Holding the wheat stocks in the region where acquired at a storage cost of $0.625 per metric ton per month
- Selling wheat (in either region) when the market price reaches the regional price ceiling
- Buying wheat (in either region) when the market price falls below the regional price floor
- Selling all remaining wheat stocks after 50 years at prevailing market prices.

The price band for the U.S. operations of the fund was fixed at $140 to $220 per metric ton. After experimenting with a few different sets of rules, four cases were run with the above rules in force and the policy specified as in Table 2.1. The initial stocks were selected in such a way that the fund could operate under the

TABLE 2.1 POLICY RULES FOR FOUR CASES					
INFORMATION SYSTEM	UNITS	CURRENT		SATELLITE	
CASE		1	2	3	4
ROW PRICE FLOOR	$/MT	150	155	150	155
ROW PRICE CEILING	$/MT	258	258	258	258
INITIAL STOCKS IN U.S.	MMT	90.7	52.1	42.2	11.7

corresponding rules of acquisition and release for 50 years without running out at any time.

To compute present value of costs and benefits the interest rate on wheat inventories was assumed to be 10 percent per annum. To this was added 5 percent per annum storage cost. Transportation costs of $8 per metric ton were assumed to be charged to importer when wheat from the fund was transported from one region to the other. The overhead costs for operating the fund were assumed negligible compared to the cost of acquisitions and hence were ignored. Benefits within each time period were computed as the economic surplus by evaluating the incremental value function at the constrained optimum level of consumption, trade, storage and prices.

The accuracy of the crop forecasts (error variance) at each time of year and in each region was used to characterize the two information systems--denoted "current" and "satellite" in the next section. The actual inputs were the same as those used in ECON Report No. 76-243-1A, Table 2.11 [15].

It was assumed that the fund policy rules were announced clearly and unambiguously and followed strictly for 50 years so that the market impacts of the fund's transactions could be modeled in a straightforward manner. As with the

ECON Integrated Model, we have also assumed that all improved crop information obtainable from the LANDSAT system is published under ground rules similar to those in effect for the USDA Crop Reporting Board today, so that no differential effects of crop information need be studied.

3. RESULTS AND CONCLUSIONS

3.1 Cost Savings from Improved Information

Both benefits and costs differed significantly according to which information system was assumed. These differences were the same order of magnitude as the differences due to the specification of the fund policy. The present value of costs for operating the fund for 50 years differed by four to five billion dollars between current and satellite information systems. For a fund which is chartered to operate under the rules which we assumed, the improved (satellite) information system results in annual cost savings of about a half billion dollars over the life of the fund. The savings occur mainly, but not entirely, as a result of the reduction of required initial stocks when the satellite information system is employed. Changes in the sharpness and frequency of price "peaks" account for the remainder of the cost savings.

3.2 Benefits of the Fund

On the contrary, the annual benefits of the fund to the world are greater by approximately the same amount with the current information system than with the satellite system. (The exact difference depends on the fund rules. See Table 3.1). Benefits of the fund to the ROW consumers are approximately greater by this amount with the current information system, regardless of which rules are assumed. The main reason for the big difference in ROW benefits is found to be the substantial reduction of ROW price "peaks" afforded by the satellite information system. The fund is thus more sorely needed in the ROW with the current information system than with the satellite system. In the United States the improvement of forecast accuracy causes prices to be slightly higher in this

TABLE 3.1 RESULTS OF 50-YEAR SIMULATION OF INTERNATIONAL FOOD FUND

	CURRENT INFORMATION SYSTEM		LANDSAT INFORMATION SYSTEM	
ROW PRICE BAND ($/METRIC TON)	150-258	155-258	150-258	155-258
STARTING IFF WHEAT STOCKS (MMT)	90.7	52.1	42.2	11.7
ENDING IFF WHEAT STOCKS (MMT)	7.9	9.5	2.8	9.5
ANNUAL WORLD BENEFITS (MILLIONS OF U.S. DOLLARS)	703	535	243	101
ANNUAL IFF COSTS (MILLIONS OF U.S. DOLLARS)	1204	627	600	147
ANNUAL CONSUMER BENEFITS (MILLIONS OF U.S. DOLLARS)				
--TO U.S.	-28	-27	+1	+2.5
--TO ROW	+886	+201	+260	-306

model--hence, slightly higher total benefits result. In fact, the U.S. consumer benefits under the current information system were found to be losses, and were converted into small gains under the satellite system. The trade-off between crop information and reserve wheat stocks (fund operated) is very clear in these results.

3.3 Comment on Significance of the Results

To avoid possible confusion on the meaning of the results, it should be emphasized again that it was not our intention to compare the economic welfare of the United States and ROW with and without an international food fund in this case study. In particular, there is no attempt to measure the food security and famine relief effects which might result from a properly managed fund. The purpose here is to provide illustrative, and possibly insightful, estimates of expected benefits and costs of the fund under two different regimes of crop forecasting accuracy, and to subject these estimates to a limited sensitivity test with respect to variation of the fund policy. With a poor choice of fund policy, our results show that there can be a large consumer disbenefit or economic loss over and above the cost of operating the fund (e.g., the fourth case). With the current information system, the simulations demonstrate a large benefit to ROW consumers at a large cost due to heavy fund investment in stocks. It is not clear that this result would in fact be realized under the assumed operating rules of the fund, even allowing for the simplifications of regional aggregation and linear demand curves, because the gross economic welfare of the world is reduced by the fund's interventions in the markets. This economic loss has been approximated, and when combined with the aforementioned consumer benefits, results in smaller world benefit of an international food fund. The net economic affect of the fund, taking costs of fund

transactions into account, is a loss, as expected. Improved crop information can reduce this loss, giving a conditional benefit in the presence of a fund of specified dimensions.

4. RECOMMENDATIONS

In view of the limitations of the method of policy simulation for estimating economic welfare effect, it is recommended that the ECON Integrated Model be modified as discussed in Section 2.1 (and in more detail in Section 2.2 of the first volume of this report) to incorporate the fund policy rules directly into the global objective function and constraint set. This task has been thoroughly analyzed in the present study; but the computer resources--both CPU and programming--prevented its implementation within the existing contract, in spite of the significant improvement in computational efficiency achieved by the conversion from APL to FORTRAN. (For documentation of the computer work see the ECON Report No. 77-294-1A.)

The importance of the subject compels us to recommend that an attempt should be made to use the ECON Integrated Model to analyze food security and famine relief, in spite of the difficulty of the task. A most desirable approach would be to incorporate highly nonlinear demand curves for the food-deficient sectors. If the number of regions must be held down to two for computational reasons (as seems likely at present), the regions should be redefined to represent one group of nations which have a food surplus <u>and</u> are willing to aid the other group of nations, which have a food deficit, and are designated to be beneficiaries of foodgrain aid from the first group.

The evaluation of foodgrain reserve policy is inevitably concerned with the effects of crop shortfalls which are exceptional in some sense. The policy is established on the basis of statistics on foodgrain production and consumption which present the fund authority with averages, cycles, trends and extreme

deviations. There may occur a sequence of unusual crop years or there may be a break in the trend pattern following formation of the fund. A major shift in economic conditions (as, for instance, seems to have occurred in 1973-74) may intervene to disturb the established worldwide pattern of foodgrain production and distribution. The policy simulation has built into it one set of statistics on natural variability in wheat production, but another set with different characteristics could also be simulated. Demand shifts could be studied too, but less easily on account of the use of the demand functions to specify the global objective function in the optimization of the ECON Integrated Model. Perhaps most obviously, we would recommend running the existing version policy simulation for many years to bring out rare events such as disastrous crop failures which could be separately collected for analysis. In a similar and related vein, the policy simulation should be used to study the costs and benefits of the fund in the presence of a sequence of years which involve relative abundance in the production of foodgrains.

5. REFERENCES

1. Eaton, David J. and W. Scott Steele, "Analysis of Grain Reserves: A Proceedings," USDA Economic Research Service, ERS-634, Washington, DC, August 1976.

2. Tweeten, Kalbfleisch and Lu, "An Economic Analysis of Carryover Policies for the United States Wheat Industry," Oklahoma State University Technical Bulletin T-132, October 1971.

3. Steele, W. Scott, "Discussion of Alternative Grain Reserve Policies," FDCU Working Paper, FDCD, USA, January 31, 1974.

4. Sharples, Jerry A. and Rodney Walker, "Reserve Stocks of Grain," Research Status Report No. 1, September 1974.

5. ____, "Analysis of Wheat Loan Rates and Target Prices Using a Wheat Reserve Stocks Simulation Model," Research Status Report No. 2, May 1975.

6. Sumner, Daniel and D. Gale Johnson, "Determination of Optimal Grain Carryovers," University of Chicago, Office of Agricultural Economic Research , Paper No. 74:12, October 31, 1974.

7. Ray, Daryll E., James W. Richardson and Glenn J. Collins, "A Simulation Analysis of a Reserve Stock Management Policy for Feed Grains and Wheat," Oklahoma Agricultural Experiment Station Journal, Article J-2823.

8. Reutlinger, Shlomo, "Evaluating Wheat Buffer Stocks," American Journal of Agricultural Economics, Vol. 58, No. 1, February 1976.

9. Helmberger, Peter and Rob Weaver, "Welfare Implications of Commodity Storage Under Uncertainty," American Journal of Aricultural Economics, Vol. 59, No. 4, November 1977.

10. Samuelson, Paul, "The Consumer Does Benefit from Feasible Price Stability," Quarterly Journal of Economics, August 1972.

11. Hayami, Y. and W. Peterson, "Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities," American Economic Review, LXII, 1972.

12. Subotnick, A. and J. P. Houck, "Welfare Implications of Stabilizing Consumption and Production," American Journal of Agricultural Economics, Vol. 58, No. 1, February 1976.

13. Bradford, David F. and Harry H. Kelejian, "The Economic Value of Remote Sensing of Earth Resources from Space: An ERTS Overview and the Value of Continuity of Service," Vol. III, Part II, ECON, Inc., Princeton, NJ, Report No. 74-2002-10, December 31, 1974.

14. Heiss, K. P., "United States Benefits of Improved Worldwide Wheat Crop Information from a LANDSAT System," ECON, Inc., Report No. 76-122-1B, August 31, 1975.

15. Andrews, John, "Economic Benefits of Improved Information on Worldwide Crop Production," ECON, Inc., Princeton, NJ, Report No. 76-243-1A, April 15, 1977.

16. Massell, Benton, "Price Stabilization and Welfare," Quarterly Journal of Economics, Vol. 73, No. 2, May 1969.

17. Stein, John P. and Rodney T. Smith, "The Economics of United States Grain Stockpiling," RAND Report No. R-1861, March 1977.

18. Stein, John P., Emmett Keeler and Rodney T. Smith, "U.S. Grain Reserves Policy: Objectives, Costs and Distribution of Benefits," RAND Report No. R-2087-RC, February 1977.

19. Hillman, Jimmye, D. Gale and Roger Gray, "Food Reserve Policies for World Food Security," U.N. Food and Agriculture Organization, Rome, 1975.

20. Gustafson, Robert L., "Carryover Levels for Grains; A Method for Determining Amounts that Are Optimal Under Specified Conditions," USDA Technical Bulletin No. 1178, 1958.

21. Johnson, D. Gale and David Sumner, "An Optimization Approach to Grain Reserves for Developing Countries," Analysis of Grain Reserves: A Proceedings, compiled by David J. Eaton and W. Scott Steele, USDA-ERS, August 1976.

22. Pearce, William R., "Groping for a New World Wheat Pact," New York Times, September 11, 1977.

23. Just, Richard E., Ernst Lutz, Andrew Schwitz and Stephen Turnovsky, "The Distribution of Welfare Gains from International Price Stabilization Under Distortions," American Journal of Agricultural Economics, Vol. 59, No. 4, November 1977.

24. Konandreas, P., B. Huddleston and V. Ramangkura, Food Security: An Insurance Approach, International Food Policy Research Institute, Research Report 4, September 1978.

25. Bigman, David and Shlomo Reutlinger, "National and International Policies Toward Food Security and Price Stabilization," paper presented at the American Economic Association Meeting, Chicago, August 1978.

26. Heiss, K. P. and R. A. Fish, "A Cost-Benefit Evaluation of the LANDSAT Follow-On Program," ECON, Inc., Princeton, NJ, Report No. 76-102-3, September 15, 1976.

27. Thurow, Lester C., "ECON Evaluation of LANDSAT System," memorandum commissioned by Battelle under contract to NASA, March 8, 1976. (This memorandum is also reproduced in: "Sensitivity Analysis of the ECON Agriculture Information Models," ECON Report No. 76-102-1A, prepared for NASA under Contract No. NASW-2558, August 31, 1976.)

28. Taylor, C. Robert and Hovav Talpaz, "Approximately Optimal Carryover Levels for Wheat in the United States," American Journal of Agricultural Economics, Vol. 61, No. 1, February 1979.

29. General Electric Space Division, "Sigma Squared Study," prepared for NASA Goddard Space Flight Center under Contract No. NAS5-23412, Mod. 30, 1977.